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THE ENLARGED N.A.C.A. TANK, AND SOME OF ITS WORK

By Starr Truscott

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EARLY TOWING BASINS

When work on the original N.A.C.A. tank was begun in
1929, there were few precedents that could be used in its
design. The construction, equipment, and methods of test-
ing of most of the towing basins in existence had been de-
veloped to suit the study of models of hulls of displace-
ment craft. The resistance of such a model was determined
with the expectation that it would be divided into "fric-
tional" resistance and "wave-making," or "residuary," re-
sistance according to the Froude method and that the re-
sistance of the full-size craft would be estimated by com-
puting the frictional resistance independently and adding
the wave-making resistance obtained by stepping up that of
the model according to Froude's law.

The principal interest was in resistance at uniform
speed, corresponding to the interest of the ship operator
in the ability of a ship to maintain a certain operating
speed indefinitely with a minimum of power. What would
happen at extremely high speeds was of little interest pro-
vided that the resistance at the designed speed was low.

The towing carriages of most of the model basins were
made of structural-steel sections and plate riveted togeth-
er and usually had four wheels with hardened and ground
steel tires. The wheels ran on steel rails that resembled
railroad rails and that were machined to provide a straight,
smooth, and level course for the wheels.

The maximum speed of most of the carriages was less
than 15 miles per hour.

THE ORIGINAL N.A.C.A. TANK

With such precedents, we began the design of a towing
basin intended to test models of seaplane floats and hulls.

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These models were of craft that were not true water craft
at all but used the water only as a means of temporary sup-
port when at rest, when landing, or when taking off into
their proper element - the air. When the craft was in mo-
tion, the load on the water varied; in a take-off it changed
continually from a maximum to zero as the machine passed
from one element to the other. The water resistance varied
from zero to a maximum and back to zero as the speed in-
creased, and could not be divided into frictional resistance
and wave-making resistance in any simple manner because the
wetted surface varied continually through the take-off run.
Fortunately, the full-size aircraft were not very large -
compared with ships - and models of moderate size would rep-
resent them to relatively large scale, and thus would tend
to reduce any difficulties from scale effects.

It was clear that the new tank must have a towing car-
riage capable of high speed and that, in consequence, the
tank must be much longer than the usual ship tank and much
greater power must be provided to propel the carriage at
the greater speed. More powerful devices for stopping the
carriage at the end of the run must be installed and in or-
der to avoid sliding wheels and damage to tires and rails,
additional length must be provided for starting and stopping.

The most influential factor of all, however, was the
requirement that the cost must be rigidly restricted because
the funds available were very limited. This restriction
meant that attention - and money - must be concentrated on
the absolutely essential features of basin and carriage and
that everything else must be reduced to the barest minimum.

A workable solution of the problem just outlined was
obtained by devising methods of construction, types of
equipment, and means of operation that had never before been
used in towing basins. Among the novel features of the orig-
inal N.A.C.A. tank, which is described quite fully in refer-
ence 1, were:

1. A basin 1980 feet long, intended to give the towing
     carriage a sufficient length of run to take usable
     readings at its maximum speed.

2. Running rails made of structural H beams which, although
     not machined, nevertheless gave a sufficiently smooth
     surface for the tires of the towing carriage.

3. A towing carriage that had a maximum speed of 60 miles
     per hour (88 ft. per sec.) and hence could tow large
     models of seaplane floats at speeds corresponding to
     high get-away speeds.

4. Pneumatic rubber tires on the running wheels of the
   towing carriage, upon which the carriage ran
   smoothly in spite of the slight roughness of the
   surface of the rails and which gave greater adhesion
   than steel tires, thus making it possible to accel-
   erate and decelerate at very high rates.

In general, each of the novel features incorporated in-
to the original design has worked well and, to compensate
for a few difficulties, advantages have appeared that were
not foreseen when the original ideas were proposed. The use
of the H beam rails and the rubber tires was proposed by the
writer as a method of making a considerable saving in the
cost of the tank. It was not until the detail design was
begun that the potential effect on the starting and stopping
of the carriage, because of the greater coefficient of fric-
tion on the rails, was perceived and advantage taken of it.

The high maximum speed of the towing carriage in combi-
nation with the rubber tires provided the anticipated abili-
ty to attain speed quickly and thus to use the length of the
tank to the full in normal running. The length of the tank
was found to be sufficient for a test run of about 10 seconds
at 60 miles per hour but, at speeds under 30 miles per hour,
from 2 to 8 test points could be obtained during a single
run of the length of the tank, the larger number naturally
corresponding to the lowest speeds used. This method of op-
eration considerably increased the amount of work that could
be done in a given time.

Good as were the results obtained with the original
N.A.C.A. tank, the rapid development of seaplanes and the
increasing work required of the tank soon made it plain
that even better performance would be required, and in 1936
serious consideration was given to proposals to enlarge it.

The primary reasons for enlarging the tank were to in-
crease the amount of work that could be done in a given
time and to be able to tow larger models at higher speeds.
As has been stated, the length of the tank was found to be
sufficient to provide a run of about 10 seconds at 88 feet
per second. It was also found, however, that generally only
one point could be gotten in a run if the speed exceeded 40
feet per second. Inasmuch as a good many tests with large
models required test runs at speeds up to 50 feet per second
and, occasionally, to 60 feet per second, many of the runs
gave but one point. It was clear that, if the tank were 500
feet longer, at least one additional point per run could be
obtained at the higher speeds, and more at the lower ones,
and the time lost in accelerating and braking would become
a smaller part of the total time of the run.

Furthermore, the development of even larger and faster seaplanes was being discussed as a serious matter; and, inasmuch as tests of models of such craft would require higher speeds of the towing carriage, the proportion of single-point runs would be increased, with a consequent reduction in the amount of work accomplished. These facts indicated that an increase in the length of the basin and increases in the speed and the power of the towing carriage would be desirable.

A survey of the available space showed that the maximum amount by which the length of the basin could be increased was 900 feet and the extension of the tank by that amount was authorized. The enlarged tank was opened for work in October 1937. The relative lengths of the original and the enlarged tank can be seen in figure 1.

PRINCIPAL CHARACTERISTICS OF THE ENLARGED N.A.C.A. TANK

The most conspicuous of the features of the enlarged N.A.C.A. tank are derived directly from those of the original tank and owe their present form not only to the reasons for their first use but also to the experience obtained with them. As in the original tank, there are:

1. A basin of great length (new 2,880 ft.).

2. Rails made of structural H beams, without machining.

3. A towing carriage of very high speed (now 80 m.p.h., maximum).

4. Rubber tires on all the wheels, pneumatic on the running wheels and solid on the guide wheels.

These features, together with some related matters, will now be discussed in more detail, in order that their effects on the methods of testing models and the methods of recording data may be more clearly seen.

Basin.- The reinforced concrete basin of the enlarged N.A.C.A. tank has the following dimensions:

	Feet
Length on water, extreme	2,920
Normal width of water surface	24

                                              Feet

Normal depth of water   12

Length of 12-foot depth   2,880

    In the old part of the tank the side walls are coved
in above the water in order to bring the rails closer to-
gether and also to help reduce the waves. In the exten-
sion the side walls extend vertically above the water
level for 15 inches and then meet the horizontal lower
surface of the overhangs that correspond to the original
coves. The purpose of this change in section is to make
it possible for waves to run freely in the extension when
the wave suppressors are removed, although they will begin
to dissipate when they strike the coves in the old section.

    The two sections are compared in figure 2.

    The canopy of the extension is practically the same
in structure and arrangement as that of the original tank.

    The rails upon which the towing carriage runs are
structural H beams set with the web vertical, as in the
original tank, and are supported on chairs of the same
type as in the original tank.

    Towing carriage.- The original towing carriage of the
N.A.C.A. tank had four wheels, each fitted with a large
pneumatic tire of the type used on high-speed buses. These
tires were not a standard type of tire but were specially
made with smooth treads. The loads on each tire was about
5,000 pounds and the wheels and tires were large and heavy.

    Changing wheels and tires was a difficult and labori-
ous process and it was concluded that operation would be
better if a standard-size tire could be used and the load
per tire be thereby reduced. These objectives were accom-
plished by doubling the number of wheels and reducing their
size to suit a tire that is regularly made with a smooth
tread. Doubling the number of wheels made it possible to
double the number of propelling motors and thus to increase
the acceleration and the maximum speed of the towing carri-
age.

    The towing carriage used on the enlarged N.A.C.A.
tank, as shown in the diagram (fig. 3), was made by remov-
ing from the four corners of the old carriage the structure

that supported the wheels, the motors, and the gears, and replacing it by a new structure, within which are supported the trucks carrying the new wheels, the new motors, and the new gears. The new structure was made of steel tubing of the same type and sizes used in the old structure; it was welded in itself and to the old carriage structure.

Trucks.- The towing carriage now operates on eight wheels arranged in four groups of two. Each wheel is driven by a 75-horsepower electric motor through a worm and gear and is not mechanically connected to any other wheel. Each pair of wheels supports a truck that carries the two motors and supports the carriage through a pivot pin. The truck can rock freely on ball bearings on the pin and any slight irregularities in the track cause less vertical motion of the carriage itself than they did with the four-wheel arrangement. Automotive practice has been followed throughout and wheels now can be removed - for grinding tires, or repairs - about as easily as from the axles of an automobile.

This is believed to be the first use of equalized wheels arranged in trucks on carriages for towing basins, although it is realized that it reflects primarily the very special nature of the construction, equipment, and methods of work in use in the N.A.C.A. tank.

The service brakes are automotive and can also be operated by hand or by standard automotive air-brake equipment controlled by a pedal. In order to save weight, the compressed-air reservoirs are charged through a hose from a fixed compressor and reservoirs "ashore" and not by a compressor on the carriage.

Electrical braking - regenerative and dynamic - is provided as it was on the old carriage; a track switch is provided so that when the carriage passes a certain point the dynamic braking is automatically applied. If the carriage passes another point farther on, a second track switch operates and the air brake is applied full strength as in an emergency. The last resort in braking remains the grab brakes that were fitted on the original carriage.

The possibility that a tire may fail has been provided for by fitting under each truck, but attached to the main structure, a steel roller to receive the weight of the carriage and roll on the rail. The car need sink only half an inch to bring the roller into play.

The structure of the carriage proper is the same as in the original. Two cross girders are joined by two outside girders and a central girder, and all are made of steel tubing welded together. The deep central girder carries the dynamometer and towing gear and a cab at the forward end carries the motorman who controls the speed and braking of the carriage.

The control of the speed of the carriage is by the Ward Leonard system. Direct current is supplied to the field coils of all the motors at the constant voltage of 240 volts and the speed is controlled by varying the voltage of the current applied to the motor armatures.

A potentiometer rheostat, operated by a motor that is controlled from the towing carriage, controls the excitation of the generator supplying the armature current and thus controls both the voltage applied to the motor armatures and the speed of the carriage in either direction.

The regenerative electrical braking of the carriage is controlled by the motorman. Dynamic braking is also applied when the pedal controlling the air brakes is depressed.

The carriage draws its supply of power and its control of speed and braking from four pairs of trolley wires that extend the full length of the tank and are supported by catenary systems. One pair of trolley wires supplies independent power to the carriage for lights, driving small motors, and the like.

A second pair supplies the field current for the propelling motors, a third pair supplies the armature current for the propelling motors, and the fourth pair provides one control circuit for controlling speed and regenerative braking and another for controlling dynamic braking.

A small motor-generator set supplies 240-volt direct current for exciting the large generator, for the field current of the propelling motors, and for independent power on the carriage. A large motor-generator set, consisting of a 1,250-horsepower synchronous motor and an 850 kw d.c. generator capable of supplying up to 850 volts, supplies current at variable voltage for the armature circuits of the propelling motors.

The electrical equipment differs considerably from that

in use in most European tanks, particularly in that no
batteries are used and in that the uniformity of speed of
the towing carriage is dependent entirely on the uniform-
ity of the voltage output of the motor generator sets.

In connection with the extension of the tank, a two-
story office building was added at the south end of the
tank and the north end of the shop was extended 100 feet.

Operation of tank.÷ The data that are obtained on the
towing carriage of the N.A.C.A. tank during the tests of a
model are:

Speed

Resistance

Trim

Trimming moment

Lift developed by the hydrofoil device

Draft (or rise of center of gravity)

The equipment for obtaining these quantities (the
towing gear) consists of the dynamometer, the towing girder,
and the balance linkage and is arranged as shown on figure
4.

Speed is measured by determining the distance traveled
in a definite time. The distance is obtained from the dis-
tance tape, a steel tape 1 inch wide that extends from one
end of the tank to the other. It is secured at the south
end of the basin and rests on supporting brackets that ex-
tend below the bottom chords of the roof trusses. At the
north end of the basin it passes over a sheave and is held
under tension by a weight. Holes 1/2 inch in diameter occur
in the tape every 5 feet throughout its length.

Two sheaves, carried above the top of the main girder
of the carriage, lift the tape off the brackets and guide
it through a horizontal slot in one side of a small box.
On one side of the slot is a source of light and on the
other a photoelectric tube. The light beam normally is in-
tercepted by the tape but falls on the tube each time a
hole passes through the slot and the energy generated in
the tube causes a small solenoid to tilt a tiny mirror and
deflect a beam of light.

The time is obtained from a clock that closes a circuit for a small fraction of a second at intervals of one-half second and each time sends a small current to tilt a second mirror and deflect a second beam of light.

Both of the mirrors just described are located near the top of the dynamometer and the deflections of their beams of light are recorded on photostat paper in the camera on the top of the tube.

Resistance is measured from the deflection of a stiff plate spring mounted at the bottom of the large tube. The pull of the model is applied to the bottom of the spring and causes a small deflection. This deflection is multiplied by a lever extending upward within the tube. A stylus at the upper end of the lever bears against a flat plate that hangs vertically from an axis and is kept in contact with the stylus by a hair spring. A small horizontal mirror rests on the axis and moves with the vertical plate.

A beam of light from a source at the upper end of the tube falls on the mirror and is reflected to the upper end of the tube and through a narrow slit in the bottom of the camera, where it falls on the same sheet of photostat paper as the beams from the distance and time mirrors. A record is obtained by moving the photostat paper across the slit at a predetermined speed and thus recording the movements of all three mirrors as lines that appear when the paper is developed.

The motion of the resistance mirror is followed by an observer - usually called the "dynamometer man" - who watches the motion of a spot of light on a screen at the side of the tube. This spot of light comes from a second source situated at one side of the recording one and, after reflection by the resistance mirror, falls on a long horizontal mirror from which it is reflected to the screen. The movements of a beam from the time mirror also can be seen on the screen, and a failure of the lamps or of the time-indicating equipment can be instantly detected.

This device has been used practically as described since the N.A.C.A. tank began operation and, after various "teething troubles" were over, has given very good results. The principal trouble with it today is that the lamps always select the most critical test point or run on which to burn out or to become temperamental.

The towing girder is a frame of welded steel tubing suspended at the two ends by stainless-steel tapes that run over the two sheaves to the end of the piston rod that rises from the damping cylinder and supports the counterweight pan. The weight on the water, or load, of the model is determined by the weight on the counterweight pan. The model is attached to the girder by the pivot fitting at the bottom.

The forward end of the girder is extended and holds a roller that has a V-shaped groove in its face and runs on the forward edge of the vertical bar of the balance linkage. The vertical bar has a T section and the outstanding leg is finished as a long knife edge to fit the groove in the roller. The length of the bar is such that the girder may be set for a model of almost any depth and may rise and fall with it to any reasonable extent without running off the bar. In extreme cases the bar can be raised or lowered by raising or lowering the whole dynamometer on screws, but the movement is very rarely necessary.

As will be seen, the vertical bar is connected to the lower ends of two bell cranks by inclined extensions. These extensions are V-shaped in plan and the vertical legs of the bell cranks are double. This construction gives the vertical bar and the bell cranks stability against lateral motions of the girder. The forward extending legs of both bell cranks are brought together and their forward ends are joined by a single straight link.

From the lower end of a central third arm of the lower bell crank a link extends forward to the eye of the dynamometer spring. The construction of the linkage then is such that the pull exerted against the eye of the dynamometer spring is always equal to the resistance of the model, no matter what the point on the vertical bar at which the pull of the resistance is applied.

Vertical staffs on each bell crank support inertia balance weights that can be so adjusted that their inertia will balance almost exactly the inertia of the girder and the model; and, in this manner, the deflection of the dynamometer spring, caused by accelerating the carriage, disappears and the time required to reach a steady reading is considerably reduced.

The dynamometer spring that is most regularly used gives a movement of the resistance line on the record of

8-1/2 inches for 18 pounds of resistance. When it is necessary to measure a higher value, the auxiliary linkage with the upper weight pan is used to suppress the zero of the dynamometer. A 10-pound weight in the upper pan deflects the dynamometer spring forward and it requires a 10-pound pull on the vertical bar to bring the spring back to zero.

The dynamometer is calibrated by placing weights in the pan on the forward link, where they produce deflections of the dynamometer spring exactly as do pulls on the vertical bar.

If the zero reading of the resistance beam when viewed in the telltale screen is not on the zero line, it can be adjusted by a slight change in the tension of the adjusting spring that is located at the upper end of the forward link.

The entire linkage is constructed of steel tubing and plate welded together and all the joints are fitted with ball bearings specially selected for concentricity and radial clearance. The visitor may think the bell cranks and links rather crude in appearance but the workmanship used in locating the centers and insuring that the lengths of all the parts are correct is of the very best.

The knife edge on the vertical bar is the only one in the system. The use of ball bearings in this service has been very successful but the secret of the success is the fact that no matter how smoothly the carriage runs there is always a vibration of small amplitude but fairly high frequency. When vibrating in this manner, ball bearings have practically no friction and are as effective as knife edges -- and much simpler to use in construction.

The maximum movements of the linkages are extremely small - a 100-pound pull (rarely encountered) would cause the dynamometer spring to deflect about 0.05 inch at the lower eye. The actual measuring deflection, however, always corresponds to the range between zero and 18 pounds because the weight in the upper pan counterbalances all but the last 18 pounds. Although the device does not give a measurement at zero position it is near enough for practical purposes.

With models of normal size, 7 to 9 feet long, the usual accuracy with which the various quantities are measured is believed to be as follows:

Speed, ft. per sec.	±0.1
Resistance, lb.	±.1
Trim, degrees	±.1
Trimming moment, lb. ft.	±1.0
Load, lb.	±.2
Draft, in.	±.1

In special cases, these values may be bettered to suit requirements; and, on the other hand, the conditions of the tests may make it impossible to realize them.

The methods of measuring the trim and the trimming moment are illustrated in enlarged detail at the side of figure 4. For a free-to-trim test the actual center of gravity of the model is made to fall at the point corresponding to the center of gravity of the full size - the pivot point - by balance weights, horizontal and vertical. The horizontal weights are usually inside the model, the vertical ones are fitted on the staff seen in the figure. Any motion of the model about the axis (center of gravity) is indicated by a pointer that swings with the model and indicates on a scale on the top of the girder. This scale is read by the observer seated alongside the model.

In free-to-trim tests the wing lift is simulated by the pull from a hydrofoil that runs submerged at the right rear of the carriage. The hydrofoil is mounted on the lower end of a steel blade, the upper end of which is carried on a pin in the lower end of a vertical bar that operates between guide rollers. The angle between blade and bar, and hence the angle of attack of the hydrofoil, is controlled by adjusting screws. The angle of attack of the hydrofoil does not vary automatically with the trim of the model.

The downward pull of the hydrofoil is transmitted through the vertical bar into the wire rope by which it is suspended and thus to the axis at the center of gravity of the model.

The lift generated by the hydrofoil is measured by a ring dynamometer in the line between hydrofoil and model, the extension of which is indicated by a dial gage that reads to 1/10000 inch. A simple calibration enables the lift to be obtained in pounds.

When the tests of the model are to be made according to the general method, first suggested by Seewald (reference 2) and developed by Schröder (reference 3), the hydrofoil gear is tilted up out of the water and disconnected and the device is arranged to measure the trimming moments, as shown in the lower right-hand diagram of figure 4. The load of the model is varied by changing the weight on the counterweight pan. The trim is fixed, and any attempt of the model to change trim will be resisted by the trimming-moment spring. The deflection of this spring, which is a measure of the trimming moment, can be read in thousandths of an inch on a dial gage that measures the motion of the end of the pointer. The deflection of the spring is so small (0.1° for maximum moment) that neither trim nor resistance is changed enough to affect the measurements.

The rise when free to trim, or the draft at fixed trim, is indicated by the motion of the pointer on the end of the staff that rises above the middle of the girder, as it moves up and down over a scale. Usually the scale is set to read zero when the keel of the model at the step touches the water.

Two electric tachometers are operated from the shaft of one of the propelling motors. One is placed at the motorman's position and is used to indicate the speed at which the carriage runs; the other is mounted under the carriage to the left of the model and above it. This tachometer is mounted in a frame upon which are set figures representing the run number, the date, and the model number. The run number, the date, and the model number appear on both back and front, the speed only on the front. Photographs may be taken from a number of positions forward and aft of the model and provide a very good qualitative record of the performance of the model.

The enlarged tank and the altered carriage have operated practically as expected. The anticipated gain in the number of points read per run has been obtained without difficulty. The maximum number of points recorded in one run before the enlargement was 12 although the usual maximum was 8. It is now easily possible to record regularly 14 or 15 points at the slower speeds.

THE METHOD OF TAKING AND RECORDING DATA

In the earlier work of the N.A.C.A. tank the tests were all of the specific type and the data were expressed quantitatively in feet per second, pounds, and pound-feet. After the introduction of the general method of testing it became apparent that a better method of expressing the data was necessary and, with few exceptions, the data from the general type of test are now expressed in the form of the well-known nondimensional coefficients.

Load coefficient $\qquad C_\Delta = \dfrac{\Delta}{wb^3}$

Resistance coefficient $\qquad C_R = \dfrac{R}{wb^3}$

Moment coefficient $\qquad C_M = \dfrac{M}{wb^4}$

Speed coefficient $\qquad C_V = \dfrac{V}{\sqrt{gb}}$

Draft coefficient $\qquad C_d = \dfrac{d}{b}$

in which, in the N.A.C.A. tank,

Δ is weight on water, or load, lb.

V, speed, feet per second.

R, resistance, lb.

M, trimming moment, lb.-ft.

d, draft, ft.

w, specific weight of water, lb. per cu. ft.

b, beam of hull, ft.

g, acceleration of gravity, 32.2 ft. per sec.^{2}

To these coefficients should be added the ratio Δ/R. It should be remembered that in America this ratio is used as

generally as ϵ, the planing number, is used abroad and that $\Delta/R = 1/\epsilon$.

It is relatively easy to obtain much of the data directly in coefficient form. The maximum load of the model is made to correspond to a round value of C_Δ and the load is varied by amounts that correspond to definite values of C_Δ, usually 0.10, 0.05, and 0.025. The weights for providing these amounts are covered metal boxes and the correct weight of each is obtained by fitting sheet lead and fine shot into pockets inside the box.

The method of taking and recording data can best be understood by following the operation in detail for a part of a test of N.A.C.A. model 74-A, made according to the general method.

Before the test begins, it is decided at exactly what speeds, loads, and trims the data will be taken. The ranges for the various quantities are usually decided from experience and information concerning the type or the purpose of the form that is to be tested.

Speeds are not prescribed by coefficient because they cannot be set with sufficient accuracy. Instead, the speeds are prescribed in steps of 1 or 1.5 feet per second in the region of the hump and below, 2 or 3 feet per second just after the hump, and usually 5 feet per second at high speeds.

Loads are prescribed by coefficient, usually beginning with C_Δ = 0.025 or 0.050, then C_Δ = 0.10 and continuing to increase by values of C_Δ = 0.10 to the maximum to be investigated.

Trims can be prescribed to degrees or half degrees. Usually the trim is varied by 2° increments over a range that will include the zero moment and the lowest resistance.

It should be emphasized, however, that no program is rigid. If anything develops during a test that indicates a need for a change or an extension, the program is altered to suit the need. Each set of data is plotted immediately after it is obtained and the program may be modified continually as required.

The crew required for making a test according to the general method consists of the following:

(1) A motorman is stationed at the forward end of
    the centerline girder. He controls the speed
    of the carriage as directed and endeavors to
    make it precisely what was called for but ob-
    serves a tachometer and records the speed in-
    dicated.

(2) A "dynamometer man" is stationed at the dynamom-
    eter. He observes on the screen of the dyna-
    mometer the motion of the spot of light that
    indicates the resistance, records its position
    for each set of data, and operates the switch
    that causes the camera to take a record. Be-
    fore starting operation, he checks the zero
    reading and, during the run, he makes such
    adjustments of the zero as are necessary by
    putting weights in the zero correcting pan.

(3) A crew chief is stationed beside the towing
    girder. He sets the trim at which the model
    is to be towed and reads the draft and the dial
    indicating the trim moment while it is being
    towed. (In free-to-trim tests he reads the
    trim, the rise of the center of gravity, and
    the dial that indicates the lifting force de-
    veloped by the hydrofoil.) He also acts as a
    captain for the crew, records and plots the
    data, run by run, and directs changes in load
    and speed.

    In the absence of the project man he is in charge
    of the tests.

(4) A "weight man" is stationed just behind the large
    damping cylinder and the counterweight pan.
    He changes the weights on the pan, when and as
    directed, in order to produce definite loads
    on the water.

(5) The "project man" has no fixed station. He is in
    charge of the test and observes and records
    the behavior of the model as it is related to
    any of the variables. He may change the pro-
    gram as he desires.

(6) The man at the control desk keeps the voltage of
    the field current constant, notes the maximum
    armature current indicated, and notes the speed
    indicated by a voltmeter in the armature cir-

cuit that is calibrated in feet per second.
On signal from the carriage, he reverses the
motion of the carriage. He can stop the car-
riage at any time and, if desired, could con-
trol its speed.

The model to be tested is secured to the towing girder
by the fitting that is suspended on the pivot. The loca-
tion of the pivot is made to coincide as nearly as feasible
with the position of the center of gravity of the full-size
seaplane and the model is ballasted to bring the horizontal
position of the actual center of gravity vertically under
that position. If the model does not represent an actual
machine, the pivot is located somewhere near what would be
a reasonable position for the center of gravity if the hull
were part of a complete machine.

The model is set to the trim to be investigated and
the draft gage is set to read zero with the keel at the
main step just touching the water.

The upper part of a fixed-trim data sheet as it is
prepared by the crew chief with the test data filled in
is shown in figure 5. Most of the items in the heading
are self-explanatory, but J.O. gives the "job order" or
accounting number to which the costs of the test are to
be charged and C.M. the position of the center of moments.
F.S.D. shows that for a change in resistance (C_R) of
0.1 the deflection of the light spot on the screen is
6.94 inches. The notation "windage compensated" indicates
that in this particular test the windage of the exposed
parts of the towing gear was balanced by that of a disk
mounted on an extension of the upper inertia balance staff.

The time of beginning the run is entered on the sheet
and the run number is placed adjoining. Several points
may be obtained on the run and the first point is given
letter a; the others follow in sequence. The predeter-
mined load for the first point is indicated as a coeffi-
cient (in this case 0.3) and the load for each successive
point is similarly indicated.

The motorman is told that the speed will be 25 feet
per second and that there will be 5 points. The weight
man is told that the first load will be a coefficient of
0.3 and that the coefficients will increase to 0.7 by in-
crements of 0.1. The dynamometer man reports that the
zero correction is zero, that is, that there is no weight
in the zero correcting pan.

The carriage is started and the motorman endeavors
to bring the carriage to exactly 25 feet per second as
quickly as he can. He overshoots slightly and finds the
tachometer reads 25.3 when the speed becomes constant.
When the carriage is at constant speed, he signals and a
set of readings is taken.

The crew chief finds that the dial on the trimming-
moment spring indicates a deflection of 2/10000 inch and
the draft of the model is 1.4 inches. The dynamometer
man finds that the deflection of the light spot indicat-
ing resistance is 3.8 inches.

The dynamometer man takes whatever time he deems
necessary to get a good record of resistance, usually not
less than 5 seconds, then signals the crew chief. If the
latter has his own readings to his satisfaction, he sig-
nals the weight man who removes a $C_\Delta = 0.1$ weight from
the counterweight pan, thus raising the load to $C_\Delta = 0.4$.

The crew chief signals for a new reading and the
process is repeated. The repetition continues until the
end of the tank is reached - in this case without a change
in speed.

At the end of the run the motorman reports the read-
ing of the tachometer to the crew chief who enters it un-
der "V Rdg." The dynamometer man reports his successive
readings as inches of deflection and they are entered under
"R Rdg." He also reports that for the last point he sup-
pressed the zero by $C_R = 0.05$ and the correction is en-
tered under "zero corr." A zero correction of 0.05 corre-
sponds to a deflection of the light spot of 1/2 of 6.94
inches or 3.47 inches. This correction is called 3.5
inches and added to the 5.5 giving "R net" of 9.0. It
will be noted that the correction is added from then until
run 37f, where an R reading of -0.4 was observed.

The data having been noted, the model is lifted from
the water and the carriage is returned to the south end of
the tank. While en route the data as to resistance and
moment are plotted and inspected to see how the curves ap-
pear.

As soon as the waves have quieted (usually by the
time the return is completed) another run is begun at 30
feet per second and with an initial load of $C_\Delta = 0.7$.
This time the load is reduced by stages until, at the low-

est load of $C_\Delta = 0.2$, the moment spring does not indicate and the draft appears to be zero. The last point of this run is repeated as the first of the next but, as the record shows, the motorman misses the speed and reads 28.5 feet per second instead of 30. The point at $C_\Delta = 0.2$ is followed by one at $C_\Delta = 0.1$ and then the speed is changed from nominal 30 to nominal 35 feet per second, (in reality 33.0) and the load is reduced to $C_\Delta = 0.05$.

The other notes on this sheet are self-explanatory except that the "38c" in the column headed "Photo" indicates that photographs of the spray were taken as part of the record of that point.

The data sheets go to the computers together with the developed records from the camera, and a second sheet is prepared - the "Summary Sheet" shown as figure 6.

Most of the headings of this sheet also are self-explanatory, but "Dyn. Cal. .01443" indicates that, on the record of resistance, the measured distance of the mean resistance line from the zero line in inches is to be multiplied by 0.01443 to reduce it to terms of C_R. "Moment Calibration Y-3" indicates the particular calibration to be used for the reading of the moment spring dial in order to reduce it to terms of C_M.

The true speed for each point is determined from the record by counting the record of the number of feet in a given number of seconds, is reduced to C_V, and entered under "Speed Coef."

The distance of the mean resistance line from the zero line is measured in inches, converted to C_R, and entered as "Gross R Coef." The zero correction is taken from figure 6 and entered as "Zero Coef." In this case, there is no correction for windage of dynamometer structure; if there were, it would be entered in coefficient form under "Wind. Coef." Finally under "R Coef." the algebraic sum of the "Gross R. Coef.," "Zero Coef.," and "Wind. Coef." is entered as the final value of C_R for that point. The other conversions are obvious.

The records of the points shown on figures 5 and 6 were not suitable for reproduction.

The data from the summary sheet (fig. 6) are plot-
ted on a separate sheet for each value of τ with C_V
as abscissa, C_R and C_M as ordinates, and C_Δ as pa-
rameter, giving the well-known families of curves as in
figures 7(a) and 7(b).

In order to obtain a view of the manner in which the
values of C_R and C_M vary with trim, the curves are re-
plotted as cross curves at selected values of C_V with
τ as abscissa, C_Δ as parameter, and C_R and C_M as
ordinates. The cross curves derived from the summary
sheet of figure 6 will be found on the right-hand side of
figure 8 for $C_V = 4.5$.

This description has included only a part of the data
from the tests of this model but enough to illustrate the
method. The complete data for N.A.C.A. model 74-A will be
found in reference 4.

USE OF THE DATA

As a result of our studies of methods for using data
from tank tests of models of hulls of seaplanes, we have
come to the conclusion that the relative merit with regard
to resistance of forms for hulls can be determined only by
considering each form as part of a specific complete sea-
plane and making take-off computations for each. Each
take-off computation will give quantitative results that
can be compared with similar results from the others. In
addition, there must be a qualitative comparison to deter-
mine the relative merits as to spray and, eventually, as
to porpoising and behavior in a seaway.

The methods of plotting and presenting the results of
tests that have just been described are well adapted for
this work. An example, in which the data that have just
been presented will be used, will be the best demonstra-
tion. The computation is for sea level and no wind.

Let it be assumed that it is proposed to use a hull
having the form of N.A.C.A. model 74-A, as shown in figure
9, for a very large flying boat such as has been suggested
by the United States Maritime Commission for possible fu-
ture trans-Atlantic use. Accepting the assumptions made
in that report, we have:

Gross weight . . . . 250,000 lb.

Wing loading . . . .   45 lb./sq. ft.

Engine power, nominal. . . . 12,000 b.hp. for

    take-off   15,000

The number of engines and the details of the propellers are as yet unknown but, from previous computations and experience, there is a thrust curve for a seaplane having a smaller power with four engines and it is assumed that the thrust of the propellers will be proportional to the power.

The wings are assumed to have split flaps of 20 percent chord width over 60 percent of the span and, in starting, the flaps are set 30° down. From a wind-tunnel test of a model having a somewhat similar arrangement of wing and hull, there are obtained the lift and the drag curves of the complete craft and the lifts and the drags of the various components. The curves of hull and parasite drags are corrected to suit the difference in wing loading and the drag of the hull is deducted. The maximum lift is corrected for scale, and the lift and the drag curves are corrected for ground effect. There follows:

Wing area 5,560   sq. ft.

Geometric aspect ratio (assumed). . .   10

Span.   236   ft.

Mean chord. . . . .   23.6 ft.

Height of wing above water (assumed).   20   ft.

Height of thrust line above center
    of gravity (assumed)   8   ft.

The angle of wing setting relative to the hull will have a considerable influence on the performance. If it is made too low, the hull will trim too high during the high-speed part of the run; if it is made too high, the hull will be down by the bow in flight. A compromise is necessary, but it can be made intelligently by assuming several angles and making preliminary computations for each according to the following method. It is not neces-

sary to make the complete calculation but only the part
that covers the high-speed range. In this particular
problem the angles of wing setting considered were 5°,
7°, and 9°. Inspection of a sketch showed that 9° would
be sure to cause the hull to be too much down by the bow
while cruising and this angle was not computed. The
curves of high-speed resistance for wing settings of 5°
and 7° (fig. 10) show that 7° gives a lower high-speed
resistance than 5°, and consequently:

Angle of wing setting . . . . 7°

The curves of lift and drag coefficients of the aero-
dynamic structure, assumed to be generally similar to that
of the earlier model, are now replotted against trim of
hull for an angle of wing setting of 7°, instead of against
the angle of attack of the wing giving figure 11. This new
plot is not essential but it reduces the probability of
errors.

The best size of the hull cannot be predicted from the
data from the test of the model. It may be found to be
anything between that corresponding to a load coefficient
at rest, $C_{\Delta_R} = 0.35$, and the corresponding to $C_{\Delta_R} = 1.0$
or more, according to the length-beam ratio and the other
conditions of the problem. In the case of the form of
model 74-A, the lines were drawn and the water line at rest
was assumed at $C_{\Delta_R} = 0.60$.' In other words, the form was
imagined as starting at that value of C_{Δ_R} and the flow
and spray were imagined to suit, as must be the practice of
every designer of hulls.

In this particular case, an estimate of get-away was
made for three values of C_{Δ_R} : 0.50, 0.55, and 0.60. It
was found that $C_{\Delta_R} = 0.55$ gave the best result and the
work only for that value will be described in more detail.

From the assumptions that

$$C_{\Delta_R} = 0.55$$

$$\Delta_R = 250,000 \text{ lb.}$$

and

$$w = 64 \text{ lb. per cu. ft. (for sea water)}$$

it follows that:

$$\text{beam, } b = \sqrt[3]{\frac{250000}{\sqrt{64 \times 0.55}}} = 19.21 \text{ ft.}$$

and consequently that:

$$C_\Delta = \frac{\Delta}{64 \times (19.21)^3} = \frac{\Delta}{455000} \tag{1}$$

$$C_R = \frac{R}{64 \times (19.21)^3} = \frac{R}{455000} \tag{2}$$

$$C_M = \frac{M}{64 \times (19.2)^4} = \frac{M}{8750000} \tag{3}$$

$$C_V = \frac{V}{\sqrt{32.2 \times 19.21}} = \frac{V}{24.9} \tag{4}$$

The lift and the drag of the aerodynamic structure are computed as follows:

$$L = 1/2 \times 0.002378 \times 5560 \ C_L \ V^2 = 6.60 \ C_L \ V^2 \tag{5}$$

$$D = 1/2 \times 0.002378 \times 5560 \ C_D \ V^2 = 6.60 \ C_D \ V^2 \tag{6}$$

As a first approximation, the get-away speed is assumed to be 115 percent of the stalling speed. The stalling speed is obtained from

$$250,000 = 6.60 \times 2.3 \ V_S^2$$

and

$$V_S = \sqrt{\frac{250000}{6.60 \times 2.3}}$$

$$= 128 \text{ ft. per sec.}$$

and

$$V_g = 1.15 \times 128$$

$$= 147 \text{ ft. per sec.}$$

When the resistance curves similar to figure 7 (a) for
this model are examined they show that - as might have
been expected because of the low step and low angle of
afterbody keel - there are large increases in resistance
(obviously caused by wetting of the afterbody) for a
range of speeds that includes the V_g just assumed and
for trims of 6° and above. The curves for 3°, 4°, and 5°
show no such increases. The trim at take-off, therefore,
must not exceed 5° and, if take-off occurs at 5°,

$$V_g = \sqrt{\frac{250000}{6.60 \times 1.74}}$$

$$= 147.5 \text{ ft. per sec.}$$

In this case the difference is insignificant and
either value of V_g can be used in the computations. Had
the difference been great, a study would have been made of
the limiting conditions indicated by the results of the
tests and the approximate value would have been selected
to suit.

The resistance at a few points over the hump and a
few more at the 5° trim just preceding the get-away, when
computed by the present method and compared with the
thrust at those speeds, shows that in both ranges the thrust
available for acceleration is very nearly the same. This
condition is considered a desirable one and the complete
computation is undertaken.

If the excess thrusts differed greatly, the size
would be altered - increased to decrease hump resistance
and increase high speed resistance, or decreased to in-
crease hump resistance and decrease high speed resistance -
until the desired condition was obtained.

The curve of the expected thrust in pounds is drawn
against speed in feet per second as abscissa (fig. 12) and
preparations are made to derive the curve of resistance
free-to-trim - taking into account the trimming moment
produced by the thrust. The curve will be derived to ex-
tend beyond the point where running at best trim under
the control of the pilot is possible.

A computation sheet is prepared, consisting of verti-
cal columns and horizontal lines. The columns are headed
in order with the values of C_V used in preparing the

cross curves of C_R and C_M of the model. For each of the values of C_V, the procedure is the same.

In table I three columns taken from a full sheet are reproduced for the purpose of illustrating the method. In addition to the symbols at the left, for the successive items in each column, there are given at the right the definition of each item, the unit in which it is expressed, and its derivation.

The derivation of item 8 - τ, trim (first approximation), in more detail, is as follows: Enter the moment curves of figure 8 at the value of C_M equal, and opposite in sign, to the value of C_{M_T}. Follow horizontally to a point corresponding to the load parameter of $C_{\Delta_{app}}$. It will be necessary to use care in interpolation. The value of the abscissa of the point is the approximate trim τ.

When item 12 - C_Δ - load coefficient - is found, it should be compared with the value of item 7 - $C_{\Delta_{app}}$ - and, if the agreement is not reasonable, the value of item 12 should be used as a second approximation and items 8 to 12 should be computed a second time.

The value of item 14 - C_R, resistance coefficient - is obtained by entering the cross curves of figure 8 and going vertically up the value of τ to find the value of C_R corresponding to the value of τ and C_Δ.

The values of $R + D$, obtained on the computation sheet plotted against speed on figure 12, give the curve of resistance free-to-trim.

It is assumed, however, that the craft is permitted to travel free-to-trim only to a speed of 55 percent of the get-away speed and that from then on the pilot will control the trim to give minimum resistance.

It then becomes necessary to determine at what trims the machine shall be held at high speed in order to obtain minimum total resistance. The simplest way is to determine the curves of total resistance at a number of trims and then to prescribe the trims corresponding to the lower envelope of the curves. This operation is somewhat simpler than the previous one because the fixing of the

trim τ fixes the values of C_L and C_D for the whole range of values of C_V from shortly after the hump to well beyond the assumed value of V_g.

The operation is as follows:

Assume the values of τ for which the curves are to be derived. Normally, the values range from 3° to 7° by 1° intervals but in this case we know that τ cannot exceed 5° without excessive resistance, so we assume 3°, 4°, and 5°, and obtain the values of C_L and C_D for each from figure 11.

For each value of τ assumed, a computation sheet is prepared - generally similar to the previous one - and the procedure is much the same. The columns are headed, in order, with the values of C_V covering the range of speeds to be investigated as found in the cross curves of C_R and C_M of the model, and for each of the values of C_V the procedure is the same. Table II shows three columns taken from a full sheet, with notations as in table I. The derivation of item 6 - C_R, resistance coefficient - is the same as for item 14 of table I.

From the values of $R + D$ for each value of τ, a series of curves can be plotted showing the resistance of the complete craft at the various fixed trims from near the hump to where the craft is air-borne. It will be found that the curves interlace, now one and now another being the minimum. If the trim of the machine can be controlled to keep on the minimum, the take-off will occur in the minimum time and distance.

In figure 12 the passage from free-to-trim to fixed trim is indicated by the arrow head. It will be observed that, although 4° gives the minimum resistance almost to get-away, a pull up to 5° just at the end reduces the resistance quite sharply and leads to the get-away.

In figure 12 the points indicated by triangles correspond to the tabulation at $C_V = 2.6$ free-to-trim; those indicated by circles correspond to the tabulation at $C_V = 4.5$ at fixed trim of 4°. The same symbols apply in figure 11, where the lift and drag are derived, and in figure 8, where the approximate trim and resistance free-to-trim and the resistance at fixed trim are obtained from the cross curves.

Figure 12 shows only one combination, as worked out for C_{Δ_R} = 0.55. Similar curves for other values of C_{Δ_R} can be obtained and a complete survey can be made of the effect on the resistance of the various values.

The simplest and most rapid method of estimating the time and distance to get-away that we have been able to find is given in reference 5 and it is applied in figure 12. Starting at zero speed and resistance, a line is drawn as indicated with a slope of W on g where W is the gross weight of the machine and g is the speed reached in 1 second under the acceleration of gravity. W is plotted at the scale of R and thrust and g at the scale of speed. When this line intercepts the curve of the thrust, it is turned back at the same angle with the vertical, but on the other side, and the zig-zag is continued until the get-away is reached. The time in seconds to get-away is the number of times the line is reversed, or intercepts the two curves. The distance to get-away is the sum of the respective abscissas to the points where the line reverses, reading them as distances instead of speeds. In this case the time to get-away is 83 seconds and the distance run is 7,770 feet.

This method of obtaining time and distance to get-away is especially helpful where alternative curves of resistance or thrust are encountered because it is simple to apply and yet it brings out very clearly the effect of any changes in the forms of the curves.

Comparisons to determine the relative merits as to spray, porpoising, and behavior in a seaway have not been made at the N.A.C.A. tank, but it is hoped that some day they can be made. For the present we present this brief survey of the novel features of our tank, the methods of testing models, and the methods of using the data in the hope that they will assist those who used the reports of work in the N.A.C.A. tank to understand how and why certain features are as they are and thus to use the reports with greater ease.

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TABLE I

Model 74-A Δ_R = 250,000 lb. C_{Δ_R} = 0.55

Free-to-trim, including effect of thrust acting 8 feet above center of gravity. Flaps down 30°.

Item no.	Symbol	C_V = 2.4	= 2.6	= 2.8	Definition speed coefficient	Unit	Derivation assumed
1	V	59.6	64.6	69.6	Speed	f.p.s.	Equation 4
2	V^2	3,560	4,180	4,850	Speed squared	(f.p.s.)²	V^2
3	T	52,250	51,700	51,000	Thrust	lb.	Figure 12
4	M_T	-418,000	-413,600	-408,000	Moment thrust	lb.-ft.	T × 8
5	C_{M_T}	-.048	-.047	-.047	Thrust moment coefficient		Equation 3
6	P	.836	.808	.777	Proportion of load		$1 - (V/V_g)^2$
7	$C_{\Delta app}$	.460	.444	.427	Approx. load coefficient		$P \times C_{\Delta_R}$
8	τ	7.4	8.1	7.5	Trim (1st approx.)	degrees	Figure 8
9	C_L	1.99	2.05	1.995	Lift coefficient		Figure 11
10	L	48,800	56,500	63,900	Lift	lb.	Equation 5
11	Δ	201,200	193,500	186,100	Load	lb.	250,000 - L
12	C_Δ	.443	.426	.41	C_Δ		Equation 1
13	τ	7.4	7.9	7.3	Trim (2d approx.)	degrees	Figure 8
14	C_R	.085	.087	.079	Resistance coefficient		Figure 8
15	R	38,600	39,500	35,900	Resistance	lb.	Equation 2
16	C_D	.176	.187	.174	Drag coefficient		Figure 11
17	D	4,100	5,200	5,600	Drag	lb.	Equation 6
18	$R + D$	42,700	44,700	41,500	Total resistance	lb.	R + D

TABLE II

Model 74-A $\Delta_R = 250,000$ lb. $C_{\Delta_R} = 0.55$

Fixed trim, $\tau = 4^{\circ}$ $C_L = 1.64$ $C_D = 0.12$

Item no.	Symbol	$C_V = 4.0$	$= 4.5$	$= 5.0$	Definition speed coefficient	Unit	Derivation assumed
1	V	98.5	111.8	124.2	Speed	f.p.s.	Equation 4
2	V^2	9,900	12,500	15,400	Speed squared	(f.p.s.)^2	V^2
3	L	107,000	135,200	166,700	Lift	lb.	Equation 5
4	Δ	143,000	114,800	83,300	Load	lb.	250,000 − L
5	C_Δ	.315	.253	.183	Load coefficient		Equation 1
6	C_R	.058	.063	.047	C_R		Figure 8
7	R	26,400	24,000	21,400	Resistance	lb.	Equation 2
8	D	7,900	9,900	12,200	Drag	lb.	Equation 6
9	R + D	34,300	33,900	33,600	Total resistance	lb.	R + D
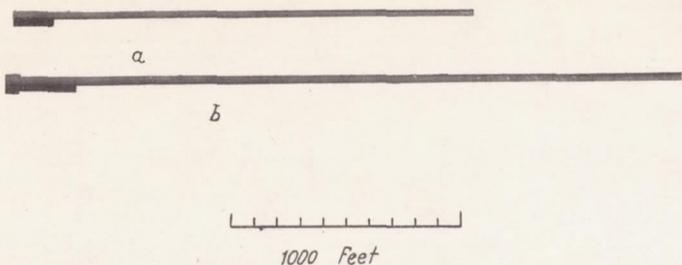
Figure 1.- The relative dimensions of the original and the enlarged N.A.C.A. tank.

Water line
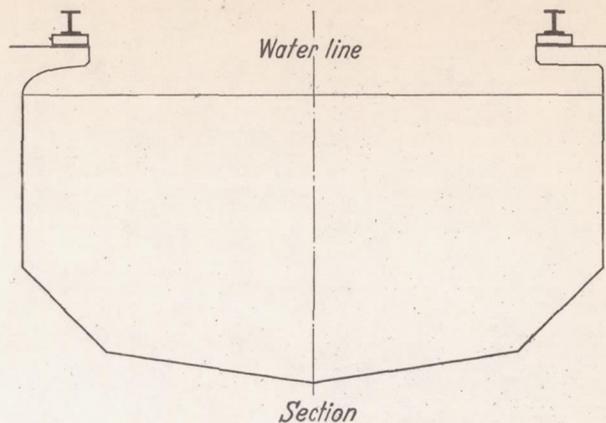
Section

Original   Extension

Figure 2.- Cross sections of the original and the enlarged N.A.C.A. tank.

A. Towing gear assembly

1 = Angle of attack adjustment	13 = Light source
2 = Hydrofoil	14 = Mirror
3 = Dashpot	15 = Stylus
4 = Towing girder	16 = Spring
5 = Lift ring	17 = Counterweights
6 = Dial indicator	18 = Indicator arm
7 = Draft scale	19 = Trim
8 = Inertia counterweight	20 = Water surface
9 = Calibrating pan	21 = Trimming-moment spring
10 = Upper pan	22 = Trim adjusting screws
11 = Zero adjusting spring	23 = Center of moments
12 = Camera	24 = Pivot (center of gravity of airplane)

B. Free-to-trim set up
C. Fixed trim set up

Figure 4.- Arrangement of the towing gear of the enlarged N.A.C.A. tank.

A

Linkage   Resistance dynamometer

see enlarged details, B & C

B

C

1 = Hydrofoil
2 = Angle of attack adjustment
3 = Running rail
4 = Guide wheels
5 = Trolley wire
6 = Distance tape
7 = Photo-electric cell
8 = Damping cylinder
9 = Towing gate
10 = Trim & moment indicators
11 = Draft scale
12 = Inertia counterweights
13 = Water surface
14 = Resistance dynamometer

15 = Spring
16 = Mirror
17 = Light source
18 = Camera
19 = Braking rail
20 = Emergency brake
21 = Emergency roller
22 = Calibrating & tare weight pans
23 = Bottom chord of roof truss
24 = Weights to counterbalance model
25 = Pivot & center of moments
26 = Frame with adjustable height
27 = Center line of motor

Figure 3.– The general arrangement of the towing carriage of the enlarged N.A.C.A. tank.

Fig. 3

J.O. 5681-B   NACA TANK   SHEET 7

FIXED TRIM DATA SHEET

MODEL NO. 74-A NAME Streamlined Hull TEST DATE Oct. 20 1937

DESCRIPTION Step modified _____ C.M. 7.20° fwd. step; 2.56 above flat on deck

F.S.D. .1 C_R OR EBS., 694 IN.   TRIM = 4°   OBSERVERS AWC·DRW·WHH EJZ-JWE

Windage compensated

TIME	RUN NO.	SPRING	DRAFT	PHOTO	LOAD	V SET.	V RDG.	R RDG.	ZERO CORR.	R NET	REMARKS
8.58	36a	2	1.4		.3	25	25.3	3.8	0		
	b	24	1.7		.4			4.8			
	c	63	2.0		.5			5.9			
	d	124	2.5		.6			7.3	0		
	e	198	3.0		.7			5.5	.05	9.0	
9.06	37a	103	2.1		.7	30	29.7	4.95		8.45	slight lateral instability
	b	60	1.9		.6			3.85		7.35	
	c	23	1.6		.5			2.6		6.1	
	d	2	1.3		.4			1.6		5.1	
	e	1	1.0		.3			.65		4.15	
	f	—	—		.2			-.4	.05	3.1	
9.14	38a	-14	.7		.2	30	28.5	3.0	0		
	b	-18	.4		.1			2.0			
	c	-9	.1	38c	.05	35	33.0	1.75	0		rough

Figure 5.- Sheet for recording data from general test.

J.O. 5681-C   NACA TANK   SHEET 7

SUMMARY SHEET FOR COMPLETE TEST

MODEL NO. 74-a NAME Streamlined Hull SCALE _____ DRG. NOS. _____

DESCRIPTION step modified _____

TEST DATE 10/27/37 DYN. CAL. .01443   MOM. CAL. Y-420

WINDAGE   CURVE Compensated   T = 4°   COMP. ALD   CHKD. DMG

DATE	RUN NO.	SPEED COEF.	DIST. FROM ZERO	GROSS R COEF.	ZERO COEF.	WIND. COEF.	R COEF.	LOAD COEF.	MOM. RDG.	MOM. COEF.	DRAFT INS.	DRAFT COEF.	REMARKS
10/20	36a	3.82	3.76	.0542	0		.0542	.3	2	.003	1.8	.115	
	b	3.87	4.77	.0688			.0688	.4	24	.053	2.1	.13	
	c	3.87	5.86	.0846			.0846	.5	63	.150	2.4	.15	
	d	3.86	7.35	.1061	0		.1061	.6	124	.304	2.9	.18	
	e	3.84	5.50	.0794	.05		.1294	.7	198	.487	3.4	.215	
	37a	4.47	4.92	.0710			.1210	.7	103	.250	2.5	.155	slight lateral instability
	b	4.47	3.81	.0550			.1050	.6	60	.143	2.3	.145	
	c	4.50	2.57	.0371			.0871	.5	23	.051	2.0	.125	
	d	4.50	1.58	.0228			.0728	.4	2	.003	1.7	.105	
	e	4.48	.65	.0094	•		.0594	.3	1	.002	1.4	.09	
	f	4.38	-.35	-.005	.05		.0450	.2	—	—	—	—	
	38a	4.37	3.03	.0437	0		.0437	.2	-14	-.018	1.1	.07	
	b	4.31	2.00	.0289			.0289	.1	-18	-.025	.8	.05	
	c	4.97	1.67	.0241	0		.0241	.05	-9	-.010	.5	.03	rough

Figure 6.- Sheet for summarizing data from general
test for plotting.
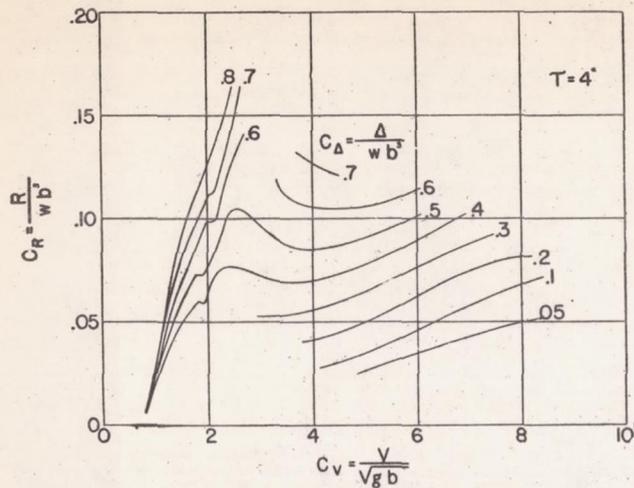
Figure 7a.- Variation of C_R with C_V at $\tau = 4^\circ$. $C\Delta$ parameter.
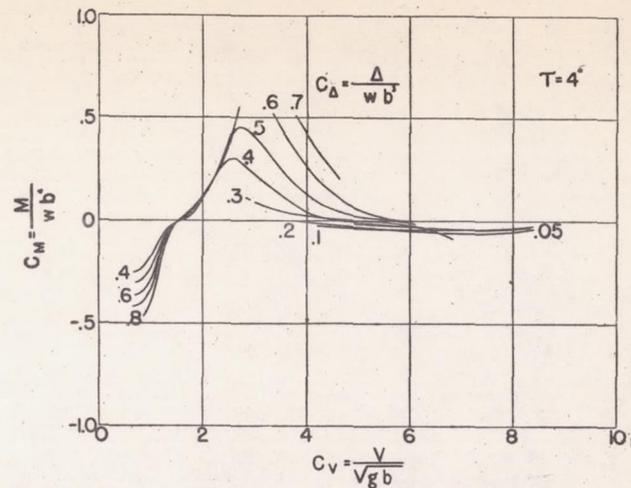
Figure 7b.- Variation of C_M with C_V at $\tau = 4^\circ$. $C\Delta$ parameter.
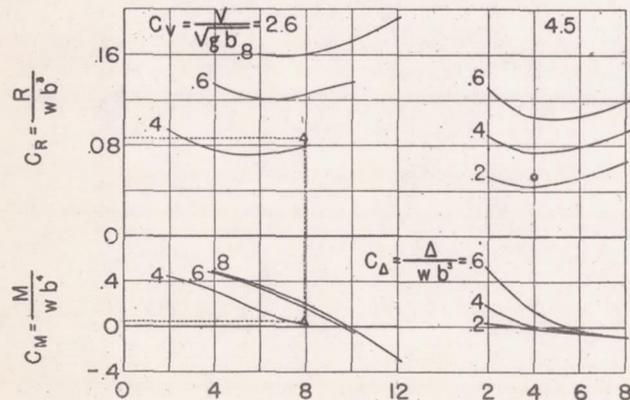

Figure 8.- Variation of C_R and C_M with τ at $C_V = 2.6$ and 4.5. $C\Delta$ parameter.
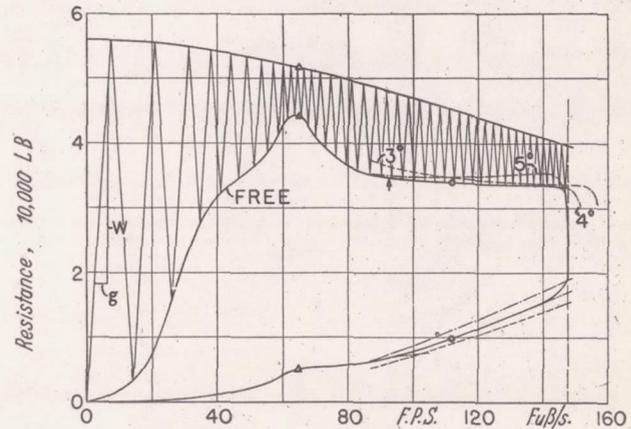

Figure 12.- Variation of thrust and resistance with speed. Construction for obtaining time and distance to getaway.
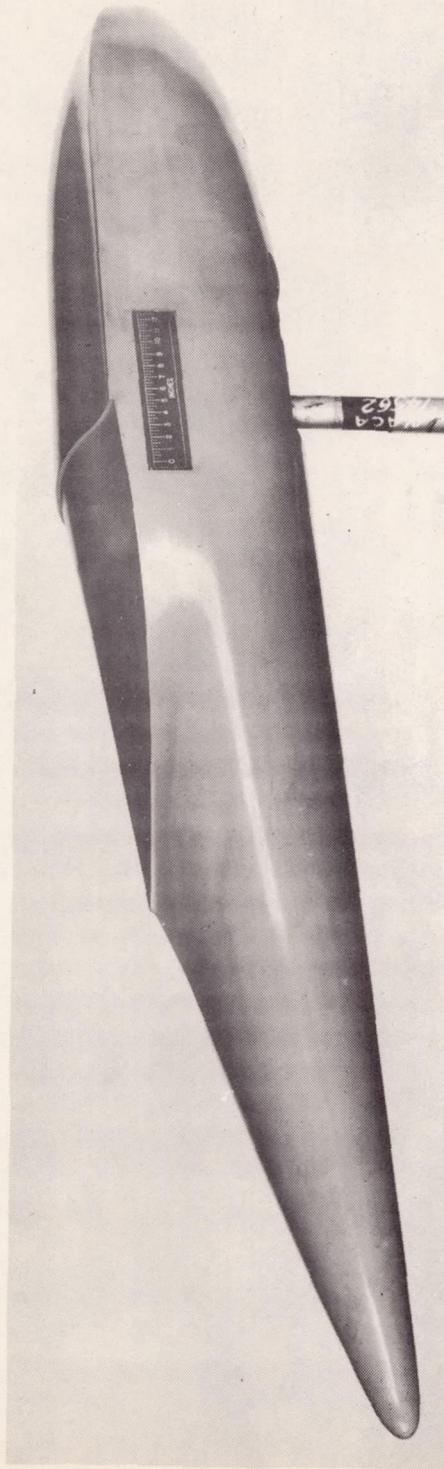
Figure 9.- N.A.C.A. model No. 74-A.
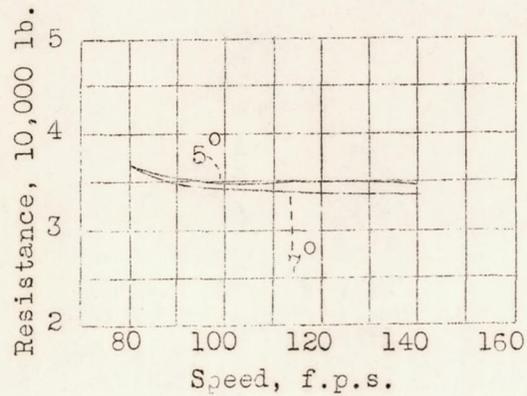
Figure 10.- High-speed resistances for angles of wing
setting of 5° and 7°.
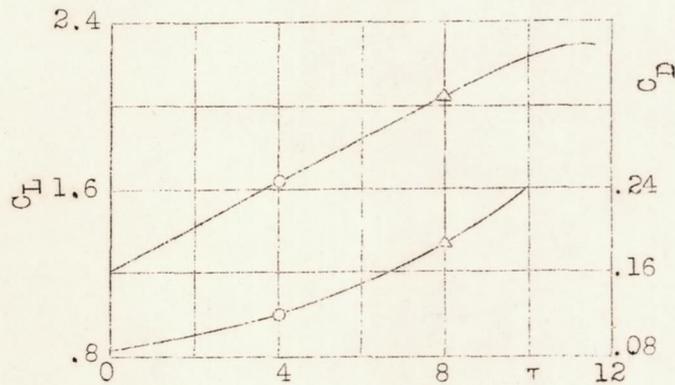
Figure 11.- Variation of C_L and C_D of aerodynamic struc-
ture with trim of hull.